Spacecraft Bus Thermal Control Subsystem

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Outline

- Requirements
  - Mission
  - Derived
  - Levied
- Trade Studies
- Preliminary Design
- Interfaces
- Open Issues
- Component Summary
- Test Matrix
- Procurement Status
- Backup
  - Mechanical Design
  - Trade Studies
  - Hardware Description
  - Analysis
  - Forward Work
  - Schedule

Mission Requirements

- **Maintain all Bus Component Temperature Limits Through All Mission Phases and Environments**
- **Maintain Instrument Interface Temperature Limits Through All Mission Phases and Environments**
- **Maintain MLI Surface Flatness to 0.25 Inch (TBR) or Less Over a 12 Inch Radius**
- **Survive AKM Environments Prior to, During and for 24 Hours Following 55 Second Engine Burn**
- **Stabilize Bus Temperatures Within 3 Hours After Leaving Eclipse**
- **Minimize Magnetometer Spin Period Temperature Variations**
- **Heater Circuits Shall Be Designed Such That the Generation of Magnetic Fields Are Minimized**
- **Design and Install MLI Blankets So As Not to Create Stray Light Exposed to the Instrument**

Environments

- **Solar Flux** — **1308 to 1400 W/m²**
- **Albedo** — **0.21 to 0.30**
- **Earth IR** — **232 to 276 W/m²**
- **Altitude** — **19324 nm**
- **Eclipse Duration** — **71 Min/Day @20 Days Max**
- **Inclination** — **28.7° - 28.9°**
- **Launch Vehicle** — **21C at Liftoff**
  1135 W/m2 at Fairing Jettison
  65C Peak Intrnl Fairing Temp
- **Sun Angle to Spin Axis**
  - **Prior to AKM Burn** — **135 to 170°**
  - **Mission Phase** — **145 ±5° (35°)**
- **Spin Rate** — **1.5 Rev/Hour**

Derived Requirements (1 of 6)

Temperature Limits (°C)	Operational	Non-Operational
• Electronics Boxes (Baseplate)	0 to 40	-10 to 50
• Battery (Baseplate)	0 to 30	0 to 30
• RCS Components (Propellant)	7 to 30	0 to 60*
• Structure	-10 to 50	-20 to 60
• Instrument Interface	0 to 40	0 to 40
• Solar Array	-80 to 100	-90 to 110
• Star Trackers (Baseplate)	-15 to 0	-30 to 50
• Magnetometers (Baseplate)	-30 to 50	-40 to 60
• Torque Rods (Baseplate)	0 to 40	-10 to 50
• Sun Sensors (Baseplate)	-10 to 60	-20 to 70
• Trim Tabs/Areas	-80 to 40	-140 to 70
• Motors	-40 to 80	-40 to 80
• Antenna (Baseplate)	-30 to 70	-50 to 100
• Release Devices	-20 to 60	-30 to 80
• Design Margin Goal	5	5

* Non Operational Implies “Dry” for RCS Components

Derived Requirements (2 of 6)

Apogee Kick Motor

- **STAR 30 BP SRM**
  - **Peak Operational Temperature Limit: < 370 C**
    - **Upper “Head” Portion of Casing**
  - **Expected Peak Flange Temperature: 350 C**
  - **Non-Operational Temp Limits: 4 to 32 C**
  - **Minimize Top to Bottom Thermal Gradient**
  - **Maintain Maximum 10C Side to Side Thermal Gradient**
    - **Insure Uniform Propellant Burn**

Derived Requirements (3 of 6)

Bus Power

- Nominal Voltage 30 ± 6 Volts

	Electronics	Heaters	Total	Max Duration
• Launch	51	25	76	30 Min
• Drift	193	86	279	35 Days
• Operations	183	86	269	5 Years
• Survival	71	65	136	TBD

Derived Requirements (4 of 6)

- **Heater Circuits**

Heater Circuit Description	Circuit Quantity	Each Watts	Total Watts
Operational and Survival			
Star Camera's	2	5	10
Magnetometer	2	3	6
Thrusters (Valve)	12	1.5	18
Sun Sensors	4	3	12
RCS Lines/Components	1	20	20
RCS Tank	1	20	20
Survival Only			
Trim Area Motors	3	3	9
Trim Tab Motors	3	3	9
Electronics Deck	3	20	60
		Total	164
Commanded Circuits			
Thrusters (CAT-BED)	12	3	36
Contingency Only Circuits			
AKM	1	60	60
		Total (All Circuits)	260
		Operational Total	86
		75% Duty Cycle	65

Values Based on Preliminary Analysis

Derived Requirements (5 of 6)

- **Electronics Box Environmental Testing Limits:**
  - **Typical Components Mounted on Electronics Deck**

• **Operational**	**0 to 40**
• **Acceptance Test**	**-5 to 45**
• **Protoflight Test**	**-10 to 50**
• **Qualification Test**	**-15 to 55**

Derived Requirements (6 of 6)

Materials

- All Components/Materials Shall Have Certification/Lot Traceability
- Environmental Testing Will Be in Accordance With NCST-TP-FM001, FAME Program Integration and Test Plan
- MLI Blankets Assembled in Accordance With SSD-PS-075
  - Meet Requirements for Outgassing
    - TML < 1.0% CVCM < 0.1%
  - Class S Redundantly Grounded With No Single Layer Exceeding 10 ohms to Any Point on Structure in Accordance With NCST-D-FM018
- Applied Optical Surfaces
  - Metalized Tapes/OSR's Provided With Some TBD Path to Ground
- Optical Property Variations Shall Be Minimized
- Optical Property Degradation Shall Be Understood

TCS Levied Requirements

- Provide 1550in² (TBR) Radiator Surface Area on Instrument Side of Electronics Deck
- Provide Aluminum Face Sheets on Electronics Deck
- Provide Commandable Heater Power (on/off)
- Provide “High Emittance” Surface Coatings on E-Deck Boxes and Cavity Surfaces
- Provide 20 (TBR) Temperature Telemetry Channels for Fault Detection of Critical Components
- Provide a Minimum Spin Period of 1 Rev/40 Minutes ± 4min During Entire Mission
- Provide a Minimum Spin Period of 1 RPM (TBR) While the AKM Is Attached, 1 Hour (TBR) Prior to and Until AKM Burn

Trade Studies

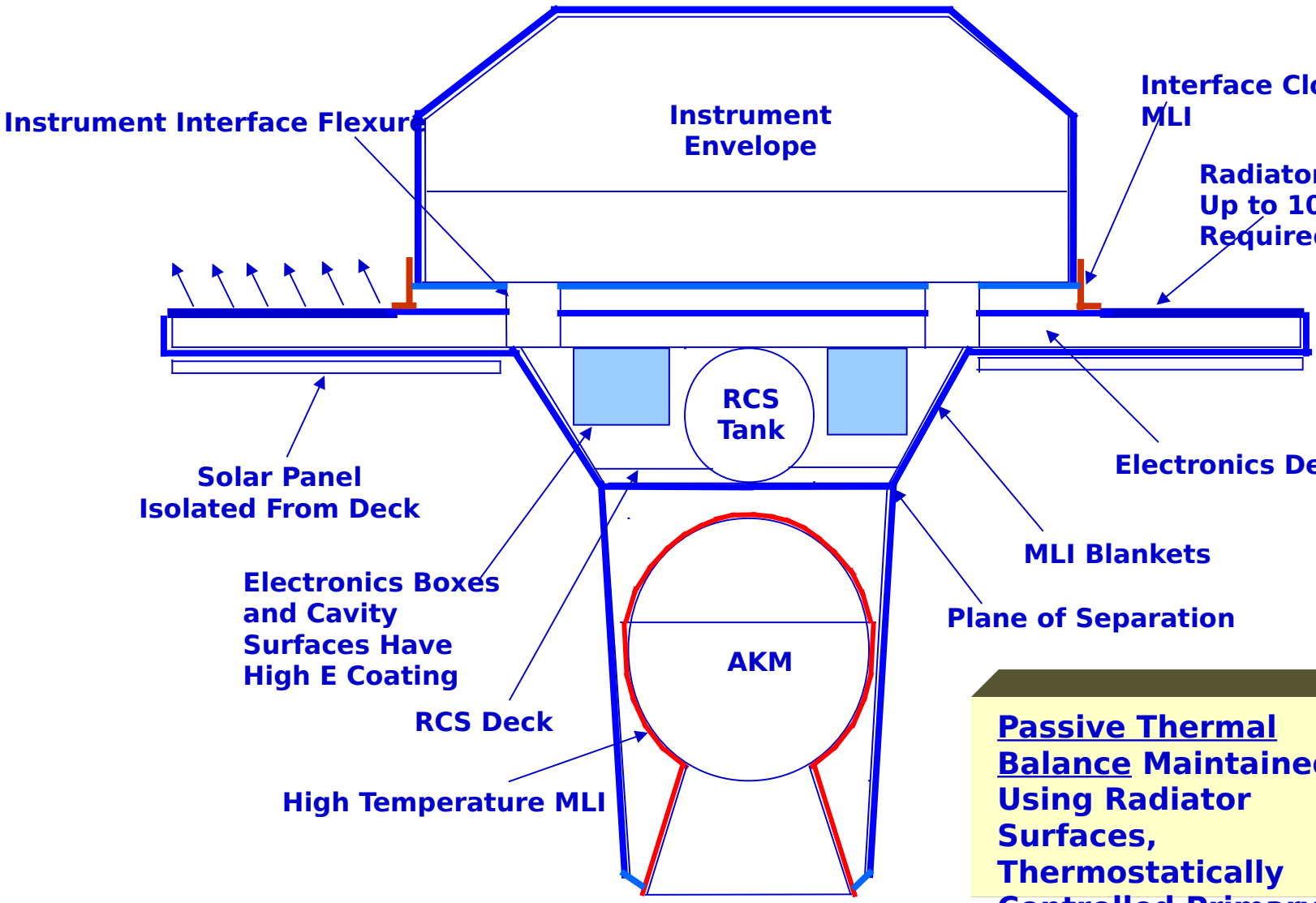
Completed Trades

- Electronics Deck Face Sheet Material
  - Composite vs. Aluminum
    - Aluminum Baselined
- AKM Jettison Time Frame
  - Design of Conduction Path to Structure vs. Immediate Jettison
    - Design Shall be Tested and/or Modified
- Sun Side Spacecraft MLI Optical Properties
  - Effects Bus Temperature/Solar Radiation Torque
    - Aluminized Kapton Baselined

Forward Work

- Battery Location/Box Layout on Electronics Deck
  - Impacts Heater Circuit Size, Moments of Inertia
    - Need to Optimize Mechanical/Thermal Design
- Radiator Size/Implementation
  - Impacts Survival Heater Circuit
    - Trade Requirements for Operations vs. Survival Mode

Preliminary Design



Passive Thermal Balance Maintained Using Radiator Surfaces, Thermostatically Controlled Primary and Survival Heater Circuits

Current Baseline Approach

Interfaces

- Bus Cone Section to Instrument Flexures
- MLI between bus and instrument – Gap Closeout
- Star Trackers Mounted on Instrument
- Antenna Mounted on Instrument
- Radiation Heat Exchange With Instrument
  - MLI Outer Layer Optical Properties on Bus/Instrument
  - Radiator Optical Properties, Size and Location Bus/Instrument
  - Trim Area/Tab Optical Properties and Range of Deployment
- Simplified Thermal Model Exchange With Contractor…FAME Delivered 9/17/01

Open Issues

- **Electro-Static Discharge**
  - **Conductive Coatings to be Used on Nonconductive MLI and OSR Materials**
- **AKM-Marmon Clamp Conduction Path**
  - **Thermal Test Planned to Determine Conductivity for Use in Model**

Component Summary

- **Thermostats**
- **Thermistors/RTDs**
- **Kapton Film Heaters**
- **Multi-Layer Insulation Blankets**
- **Optical Surface Coatings**

Test Matrix

Component	Screen Testing	TDVT	System Level Tests
Thermostats	Setpoints	x	x
Thermistors	Resistance	x	x
Heaters	Resistance	x	x
MLI	Bakeout	x	
Optical Surface Coatings		x	x

- **Major Planned Testing**
  - **Thermal Design Verification Test**
  - **Marmon Clamp Joint Conductance Test**

Procurement Status

- **Resistance Temperature Detectors (RTDs)…**
  - **Rosemount Platinum Sensors**
    - **8-12 Months**
    - **Small Purchase Award in January 02**
- **All Other Hardware Purchase Awards Due in May 02**

Backup

Trade Studies

Trade Studies (1 of 11)

Electronics Face Sheet Material

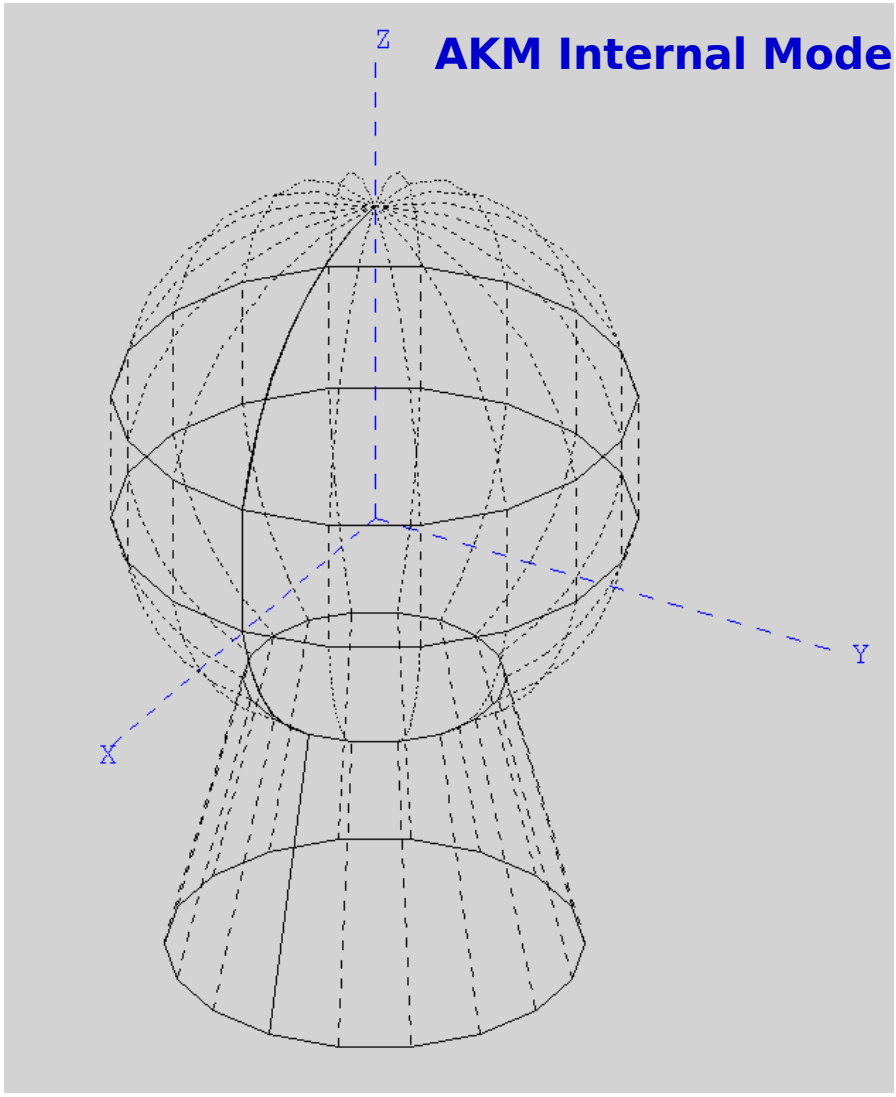
- Composite vs. Aluminum
  - Composite Requires Larger Radiator Area
  - Larger Thermal Gradients
  - No Temperature Margin in Hot Case With Available Radiator Surface Area
    - Aluminum Baselined

Trade Studies (2 of 11)

- **AKM Installation/Jettison Time Frame**
  - **Design of Conduction Path to Structure vs. Immediate Jettison**
- **Issues:**
  - **Current Marmon Clamp Design Was Qualified to 60C**
  - **Mission Controllers Need to Verify FAME Location Following AKM Burn Prior to Jettison to Insure Proper Disposal**
  - **Analysis to Date Based on STAR 37 FM**
    - **Basic Parameters Similar to STAR 30 BP**

Trade Studies (3 of 11)

- **Assumptions**
  - **Radiation Heat Loss From Nozzle Only**
  - **Upper Limit of Marmon Clamp:**
    - **60C (TBR)**
  - **Initial Temps**
    - **AKM 350C (Soak Back)**
    - **Inner Stage 20C**

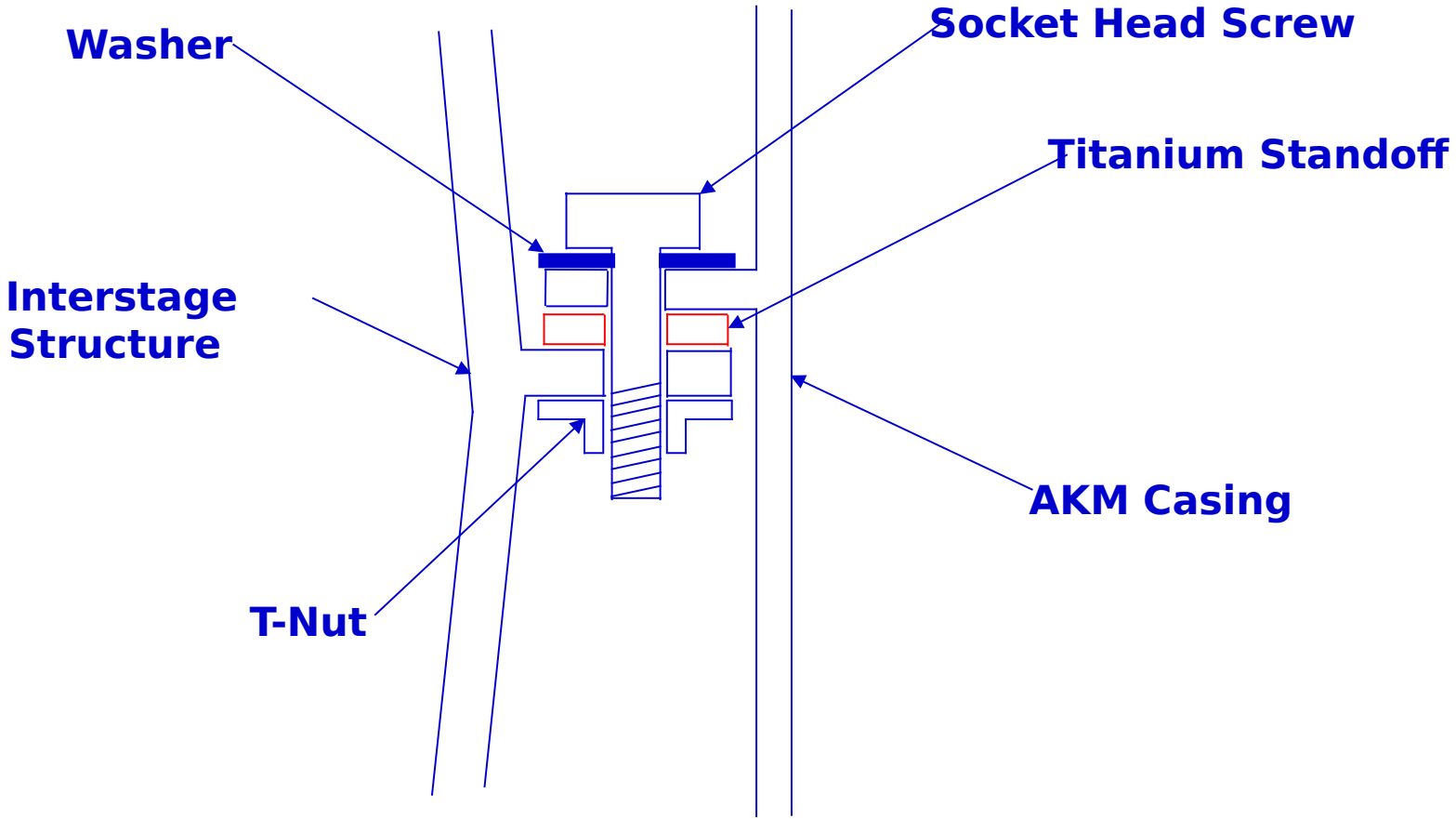


Trade Studies (4 of 11)

- **Interface Description**
  - **Inner Stage**
    - **0.125” (Now 0.090”) 6061-T6 Aluminum Construction**
    - **No Stiffeners**
    - **Solid Construction to Interface – Conservative**
  - **Fasteners (48 Places)**
    - **A286 ¼-20 Socket Head Screw**
      - **(NAS1351N4-14)**
    - **A286 0.063” THK Washer**
      - **(NAS620-C416)**
    - **A286 T-NUT**
      - **(MS21076-4N)**
  - **Titanium Spacer (48 Places)**
    - **0.5” X 1.0” X 0.125thk – With 0.265” Thru Hole**

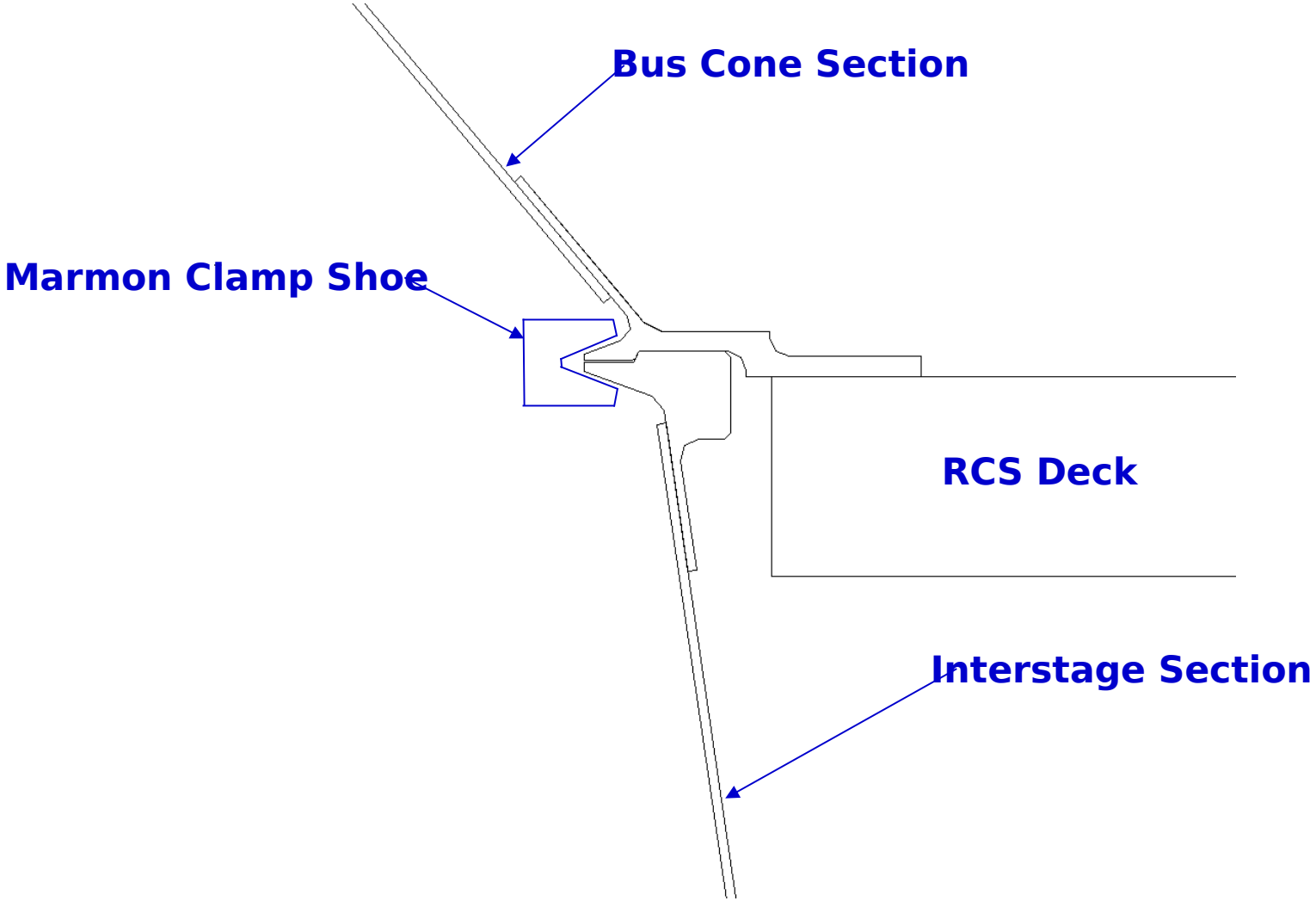
Trade Studies (5 of 11)

AKM Interface



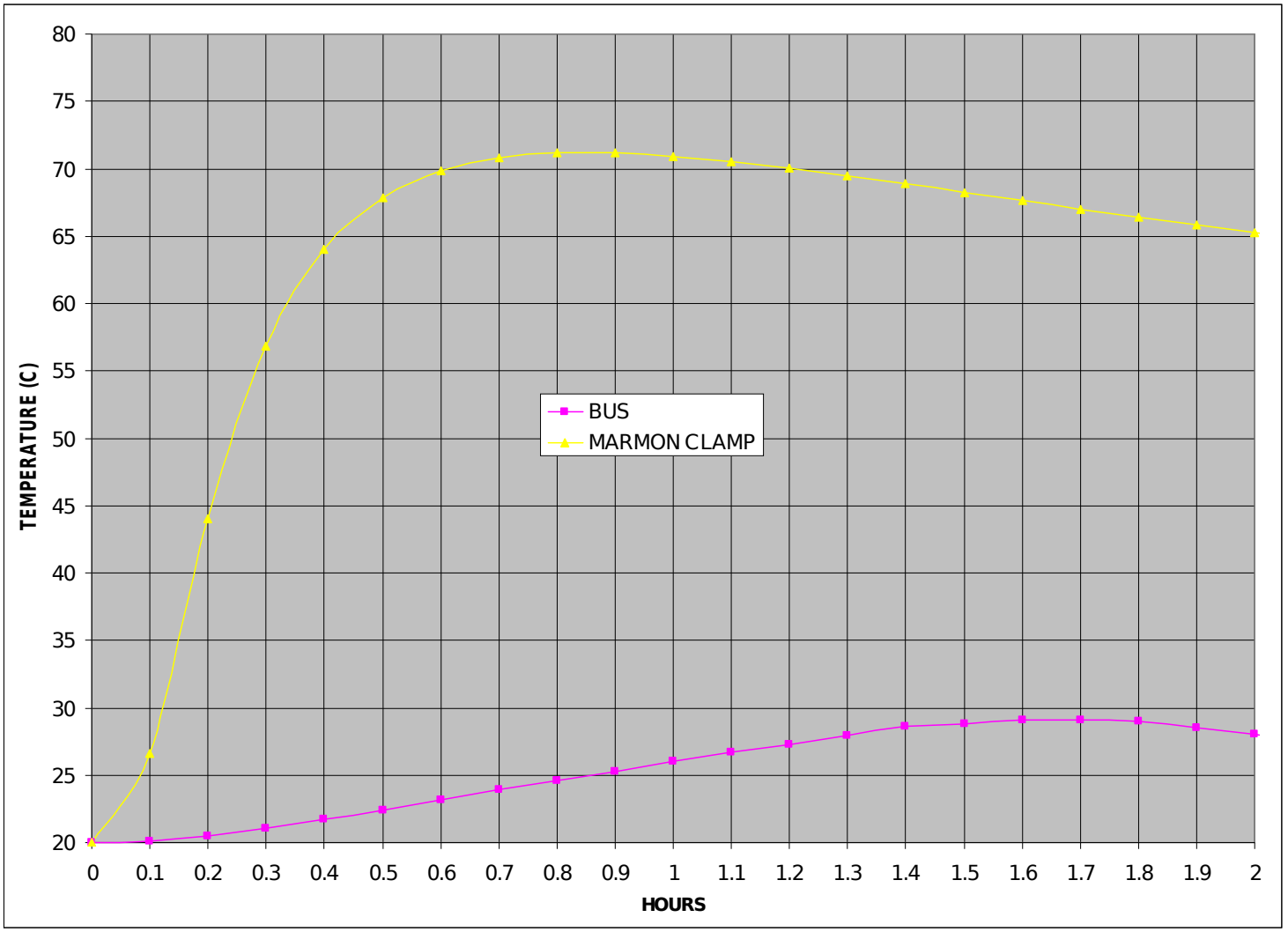
Trade Studies (6 of 11)

Marmon Clamp Interface



Trade Studies (7 of 11)

- **Marmon Clamp Reaches 60C in ~30 Minutes**



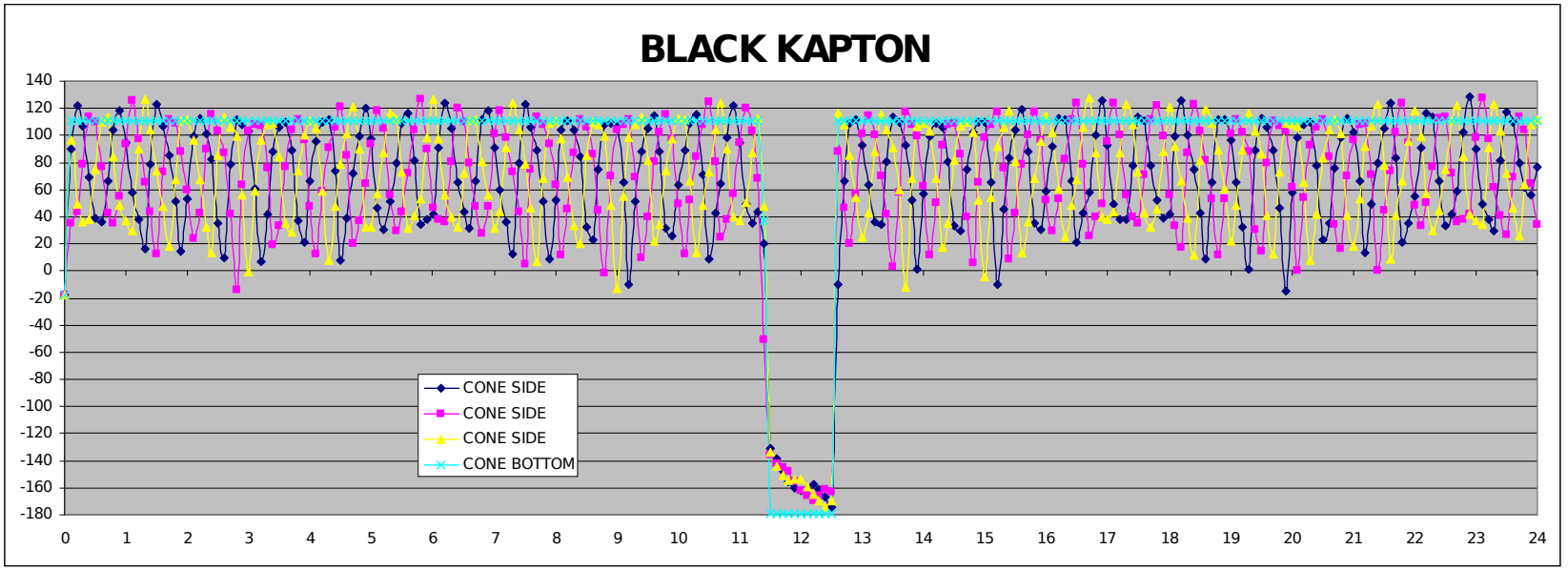
Trade Studies (8 of 11)

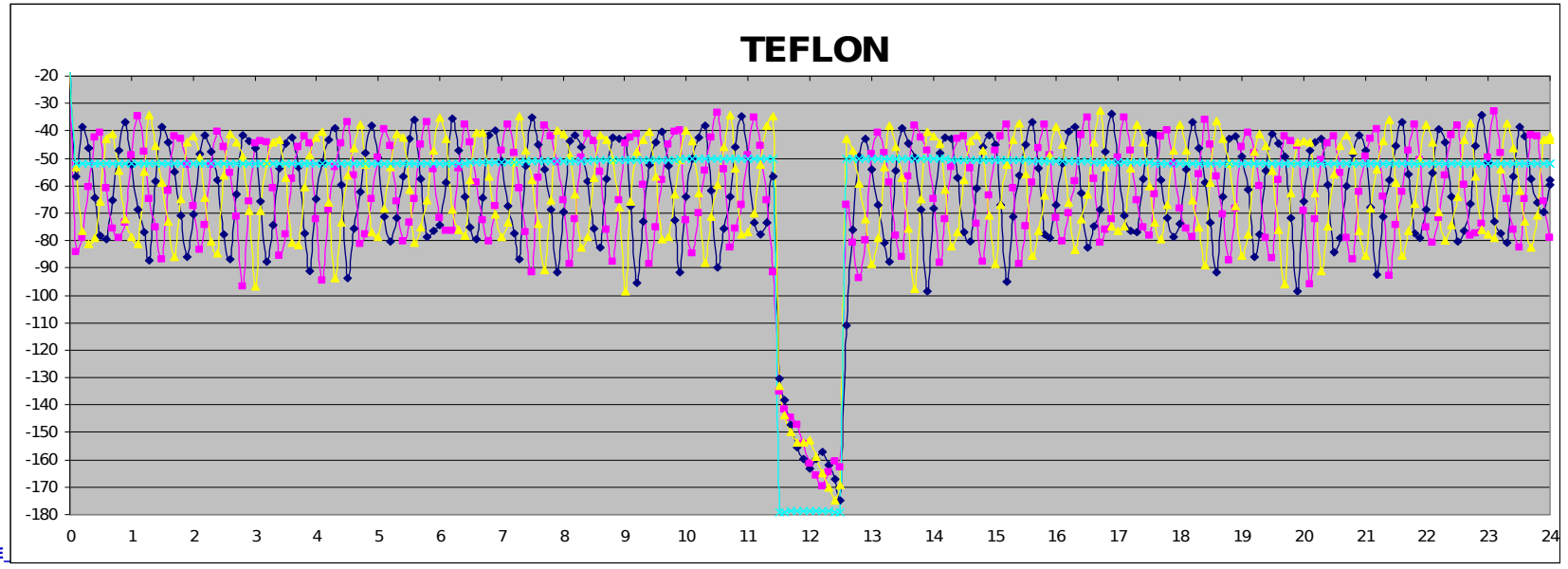
- **Observations**
  - **Peak Temperature - 71.2C**
  - **Reducing Standoff Surface Area (.5x.5) or Adding Thickness (.5) Reduces Peak Temperature 10C**
  - **Analysis Is Sensitive to Conductance to and Across Marmon Clamp**
    - **Testing Will Be Conducted in the Near Term to Determine Joint Conductance at Various Clamping Pressures**

Trade Studies (9 of 11)

- **Spacecraft MLI Optical Properties**
  - **Effect On:**
    - **Bus Temperature**
    - **Solar Radiation Torque**
  - **Need to Consider**
    - **Electrostatic Discharge**
    - **Specularity Vs. Diffuse Properties**
    - **Maintenance of Surface Flatness**

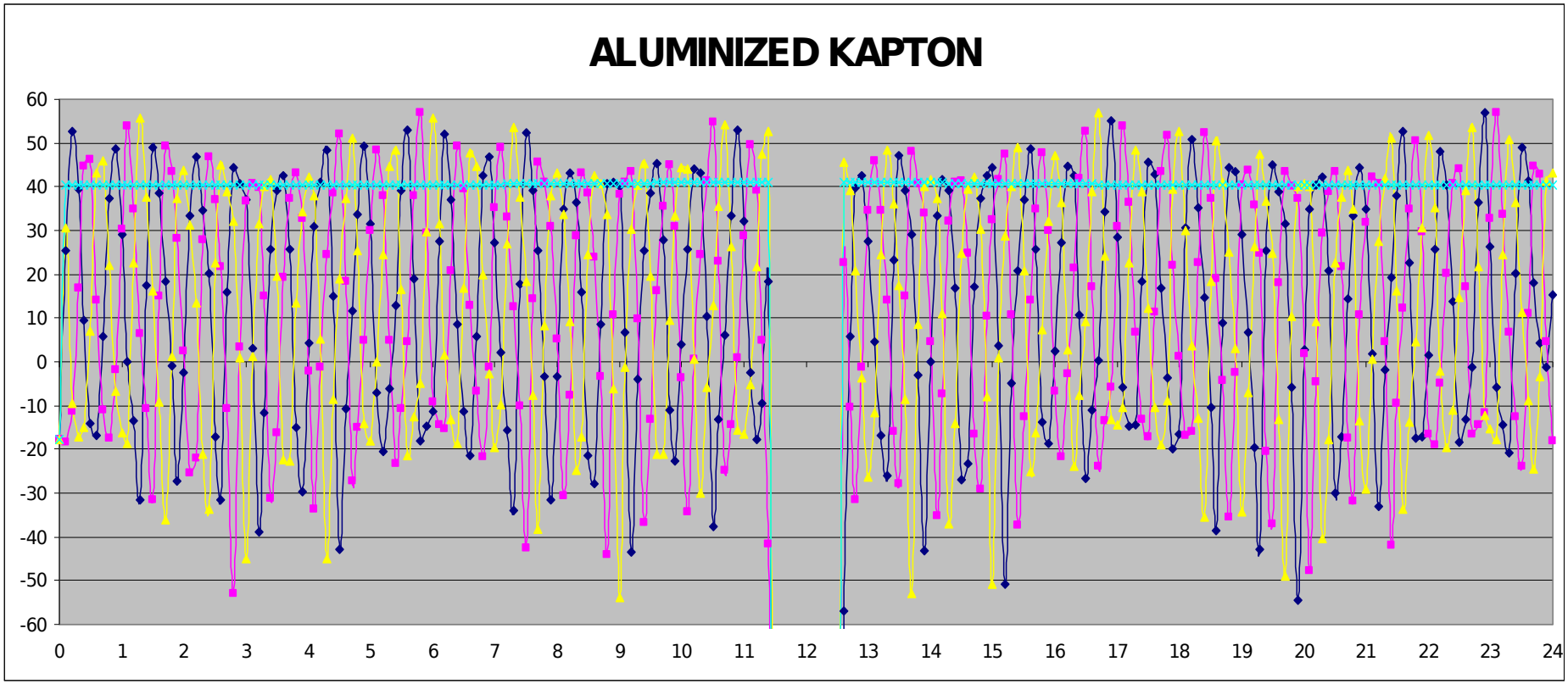
Trade Studies (10 of 11)





Trade Studies

- **Average Temperature Produced by Aluminized Kapton Is More Compatible With Requirements**
  - **Aluminized Kapton Baselined**
- **Additional Trading to Be Completed As Design Matures With More Consideration Focused on ACS**



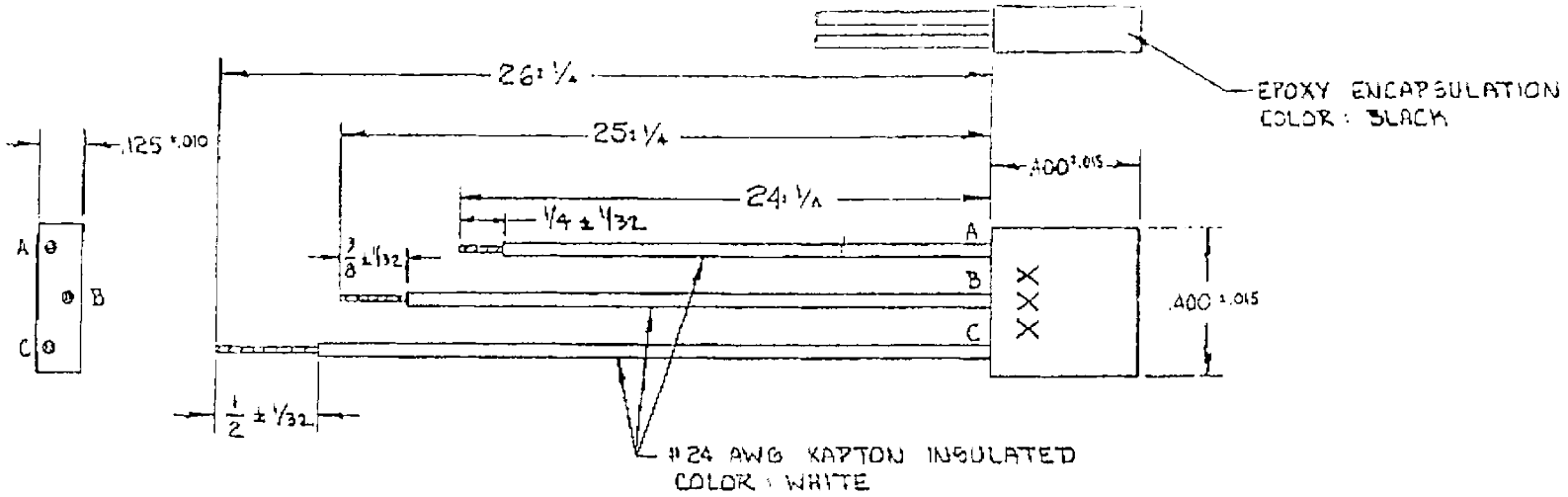
Hardware Description

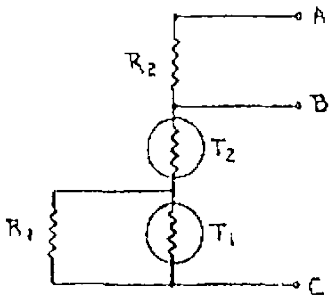
Materials List

All Materials Pass NASA Specifications for Out-Gassing (REF. 1124)

Material	*Part No.*	*Manufacturer*	*Use*
Tra-Duct Adhesive	2902	Tra-Con	Grounding
Tra-Bond Adhesive	2151	Tra-Con	Thermostats, Sensors
Transfer Adhesive	467	3M	Heaters, Velcro
RTV	CV-2946	McGhan Nusil	Boxes
Grease	CV-9042	McGhan Nusil	Boxes
Black Paint	Z306	Lord	Boxes
Dacron Scrim	B2A	Apex Mills	MLI-Separator
Fiber Glass	709714	BGF Industries	MLI-Separator
Mylar Film	DE028	Dunmore	MLI-Reflector
Kapton Film	DE294,330,335	Dunmore	MLI-Reflctr, Cover, Liner
Nomex Thread	MIL-T-43636	Synthetic Thread	MLI
Lacing Tape	20-NAT-Dacron	Gudebrod, Inc.	MLI
Kapton Tape	1205	3M	MLI
Velcro	HI-Air-Nomex	Velcro-USA	MLI
INK-Part Marking	50-700 Cat-9	HYSOL	MLI
Stainless Steel Foil	1606	Teledyne Rodney	AKM Nozzle MLI
Aluminum Foil	1100-0	All-Foils	MLI-GND
Braided Wire	1223	Alpha	MLI-GND
Female Terminal Lug	CFS-TO-1825	SPC Technology	MLI-GND
Male Terminal Lug	CMS-TO-1825	SPC Technology	MLI-GND
Staple, Stainless Steel	SP19-1/4-SS	Stanley-Bostitch	MLI-GND
Silver Teflon Tape	MO09302	Dunmore	Radiators, Trim Tabs
ITO/Germanium	TBD	Astral Technologies	Conductive Coatings

Thermistor





NOTES

1. R_o @ 25°C = 5649 Ω ± 1.5°C
2. MAX TEMP = 125°C
3. R_1 = 10,000 Ω
4. R_2 = 9530 Ω

FORMERLY LTN-11 ML

TOLERANCES: UNLESS OTHERWISE NOTED, ALL DIMENSIONS ARE IN INCHES AND TOLERANCES ARE AS SHOWN HERE. FRACTIONS = ± 1/64; DECIMALS: .XX = .01, .XXX = .005; ANGLES = ± 0°30'	DWN. GEM 10-28-88; CHECKED; APP'D 10/31/88; MFG.	FENWAL ELECTRONICS, A DIVISION OF KIDDE, INC., FRAMINGHAM, MASS. 01701	TITLE: THERMISTOR PROBE ASS'Y OUTLINE
MATERIAL		FINISH: ✓	PLATING:
SHEET 1 OF 1	SCALE —	SIZE B	DWG. NO. 534-31A604-562 REV:

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RTD

SPECIFICATIONS

1.0 SCOPE. MODEL 118BDT IS A GENERAL PURPOSE SENSOR DESIGNED TO MEASURE TEMPERATURE OVER THE RANGE -260°C TO + 200°C. THE SENSING ELEMENT IS MADE OF PURE PLATINUM WIRE MOUNTED IN CERAMIC INSULATION IN A MANNER TO ENSURE STRAIN-FREE OPERATION. THE LEAD WIRES ARE SECURELY ANCHORED IN AN EPOXY BODY TO WITHSTAND ROUGH HANDLING.

2.0 PERFORMANCE SPECIFICATIONS.

2.1 TEMPERATURE RANGE. THE USEFUL TEMPERATURE RANGE OF MODEL 118BDT IS -260°C TO +200°C.

2.2 ICE POINT RESISTANCE. MODEL 118BDT HAS AN ICE POINT RESISTANCE OF 500 OHMS $\pm$ 2 .

2.3 RESISTANCE-TEMPERATURE RELATIONSHIP. EACH SENSOR SHALL MEET THE RESISTANCE-TEMPERATURE RELATIONSHIP SHOWN IN TABLE 1 TO THE TOLERANCE INDICATED.

2.4 CALIBRATION. UNLESS OTHERWISE SPECIFIED, EACH SENSOR SHALL BE CALIBRATED AT THE ICE POINT (0°C) ACCURATE TO ±0.04°C. ADDITIONAL CALIBRATION AT -268.95°C, -195.87°C, -182.97°C, 100°C and 260°C IS AVAILABLE TRACEABLE TO NBS.

2.5 REPEATABILITY. MODEL 118BDT SHALL WITHSTAND TEN (10) CONSECUTIVE TEMPERATURE SHOCKS FROM LIQUID NITROGEN TO 150°C SILICONE OIL AFTER WHICH THE CALIBRATION AT 0°C SHALL NOT CHANGE MORE THAN ± .25°C.

2.6 INSULATION RESISTANCE. AT ROOM TEMPERATURE WITH DRY EXTERNAL SURFACES, EACH SENSOR WILL BE GIVEN AN INSULATION RESISTANCE TEST WHILE PLACED AGAINST A FLAT CONDUCTIVE PLATE. THE INSULATION RESISTANCE BETWEEN ANY SENSOR LEAD AND THE PLATE SHALL EXCEED 10 MEGOHMS WITH 100 VOLTS DC APPLIED.

2.7 TIME CONSTANT. THE TIME REQUIRED FOR 63.2 PERCENT RESPONSE OF AN UNMOUNTED SENSOR, TO A STEP CHANGE IN TEMPERATURE FROM ROOM TEMPERATURE AIR TO WATER FLOWING TRANSVERSE TO THE SENSING SURFACE AT 3FPS AND AT 76 ± 4°C IS LESS THAN 4.0 SECONDS. THIS RESPONSE TIME IS GIVEN BECAUSE IT REPRESENTS A CONVENIENT REPRODUCIBLE LABORATORY CONDITION. THE IN-SERVICE RESPONSE OF THE UNIT WILL DEPEND UPON HOW IT IS MOUNTED AND THE ENVIRONMENT IN WHICH IT IS USED.

2.8 SELF HEATING. AN UNMOUNTED SENSOR IS CAPABLE OF DISSIPATING AN I^2R POWER OF 18 MILLIWATTS WITH A TEMPERATURE RISE OF LESS THAN 1°C WHEN SUBMERGED IN WATER FLOWING TRANSVERSE TO THE SENSING SURFACE AT 3 FPS AND AT 25 $\pm$ 5°C.

2.9 VIBRATION. WHEN THE SENSOR AND LEADS ARE FIRMLY ATTACHED TO A SURFACE, THE SENSOR SHALL WITHSTAND AT LEAST 50 G'S PEAK OR 0.5 INCH DOUBLE AMPLITUDE IN ANY AXIS WHEN CYCLED FROM 20 TO 2000 HZ OVER A 15 MINUTE TIME INTERVAL.

2.10 COMPATIBILITY. MODEL 118BDT IS SUITABLE FOR USE IN ANY FLUID OR ENVIRONMENT THAT IS COMPATIBLE WITH COPPER, KAPTON AND EPOXY.

2.11 WEIGHT. THE WEIGHT OF THE SENSOR SHALL BE LESS THAN 4 GRAMS, INCLUDING LEADS.

2.12 MOUNTING. MODEL 118BDT MAY BE MOUNTED BY CEMENTING OR CLAMPING TO A SURFACE.

2.13 IDENTIFICATION. EACH SENSOR SHALL HAVE THE S/N ENGRAVED IN THE POSITION INDICATED, A PAPER TAG WITH THE FOLLOWING MINIMUM INFORMATION SHALL BE INCLUDED.

RMT INC.
MODEL 118BDT
SERIAL NUMBER ______

3.0 QUALITY ASSURANCE

3.1 REPAIR AND MAINTENANCE. THE SENSOR IS A NON-REPAIRABLE ITEM AND SHALL NEED NO MAINTENANCE DURING ITS USEFUL LIFE.

3.2 INDIVIDUAL TESTS. EACH SENSOR SHALL BE EXAMINED FOR HIGH QUALITY WORKMANSHIP, CONFORMANCE TO THIS DRAWING AND SHALL UNDERGO THE TESTS DEFINED OR IMPLIED IN PARAGRAPH 2.3, 2.4 AND 2.6. OTHER TESTS WILL BE PROPOSED ON REQUEST.

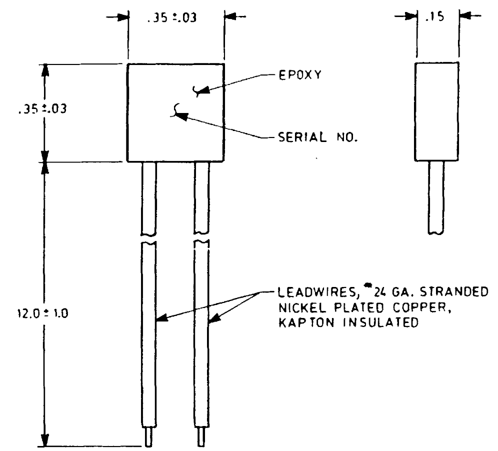
RESISTANCE TEMPERATURE RELATIONSHIP TABLE 1

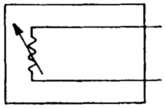
TEMPERATURE (°C)	RESISTANCE (OHMS)
-260.00	1.0
-240.00	12.4
-220.00	44.35
-200.00	85.75
-180.00	129.10
-160.00	172.15
-140.00	214.60
-120.00	255.00
-100.00	297.95
-80.00	339.00
-60.00	379.70
-40.00	420.05
-20.00	460.15
0.00*	500.00*
20.00	539.45
40.00	573.70
60.00	617.65
80.00	656.40
100.00	694.90
140.00	771.15
180.00	846.45
200.00	883.63

*DENOTES PHYSICAL CALIBRATION POINT, INTERCHANGEABLE TO $\pm$ 10 OHMS ($\pm$ 5.1°C)

REVISIONS

ZONE	REV	DESCRIPTION	CHG NO	APP'D	DATE
	A	NEW RELEASE	005630	[illegible]	[illegible]
B 4 C 4	B	REV. SPEC. 2.7 & 2.8	[illegible]	[illegible]	[illegible]




SCHEMATIC DIAGRAM

SPECIFICATION DRAWING

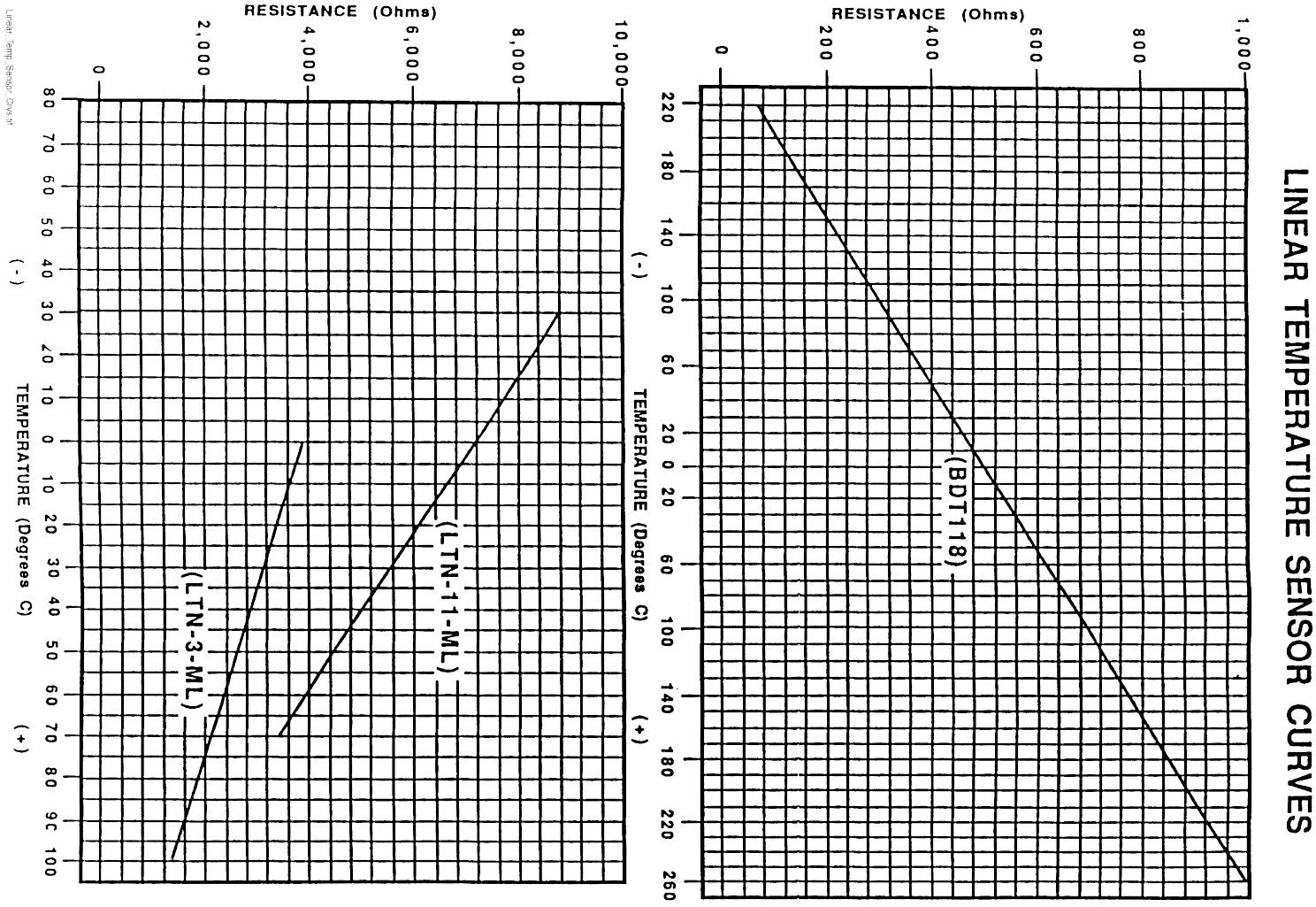
UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES. REMOVE ALL BURRS AND SHARP EDGES. MACHINE SURFACE FINISH 125
— TOLERANCES —
DECIMALS .X ± .1 / .XX ± .02 / .XXX ± .010; FRACTIONS ± 1/32; ANGLES ± 2°
DO NOT SCALE PRINT

CONTRACT NO.
DR R.D. BRUNS 5-19-84
CHK'D B#B 5/23/84
APP'D 5/15/84
APP'D GOVT.

Rosemount MINNEAPOLIS, MINNESOTA
TITLE SENSOR, SURFACE TEMPERATURE
SIZE C | FSCM NO. 60678 | DRAWING NO 118BDT
SCALE 4/1 | WT --- | SHEET 1 OF 1

Sen_Surface_Temp.tif

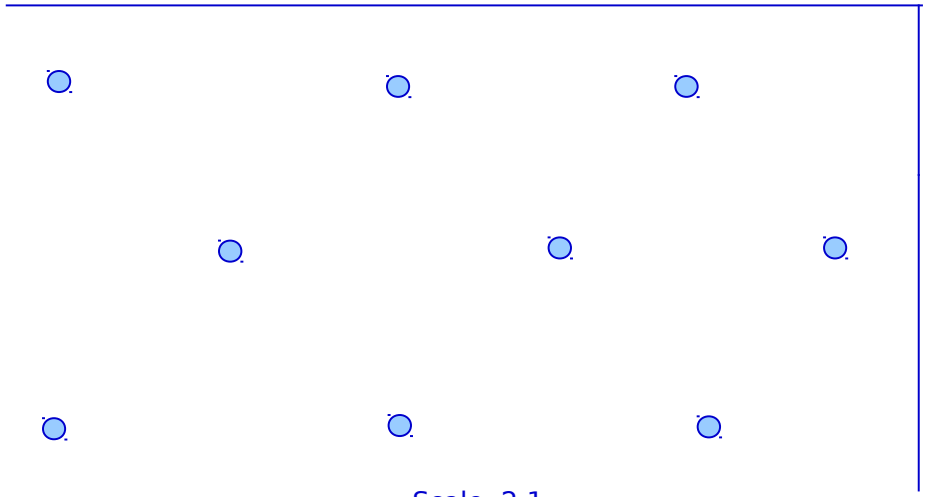
Sensor Curves



Stray Light Prevention (1 of 5)

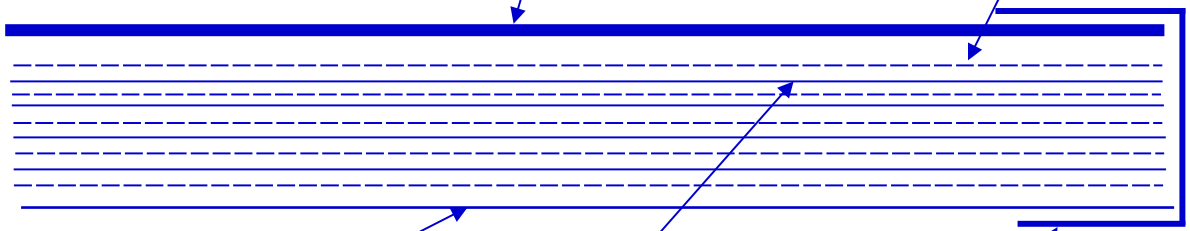
- **Assumptions:**
  - **All Blankets Are Designed to Vent Inboard**
    - **All Interior Layers Are Provided Either Perforated or Loose Meshed**
  - **Vent Paths Are Provided From the Blankets, Either Into the Spacecraft or Through Small Voids in Attachment Tapes**
    - **About 0.5 Inches Spaced 6 Inches Apart in the Tape Holding the Blankets to the Structure**

Stray Light Prevention (2 of 5)



Typical Reflector Layer Perforation
Dunmore Pattern #101

Stray Light Prevention (3 of 5)



Outer Layer
- Supplied Non-Perforated

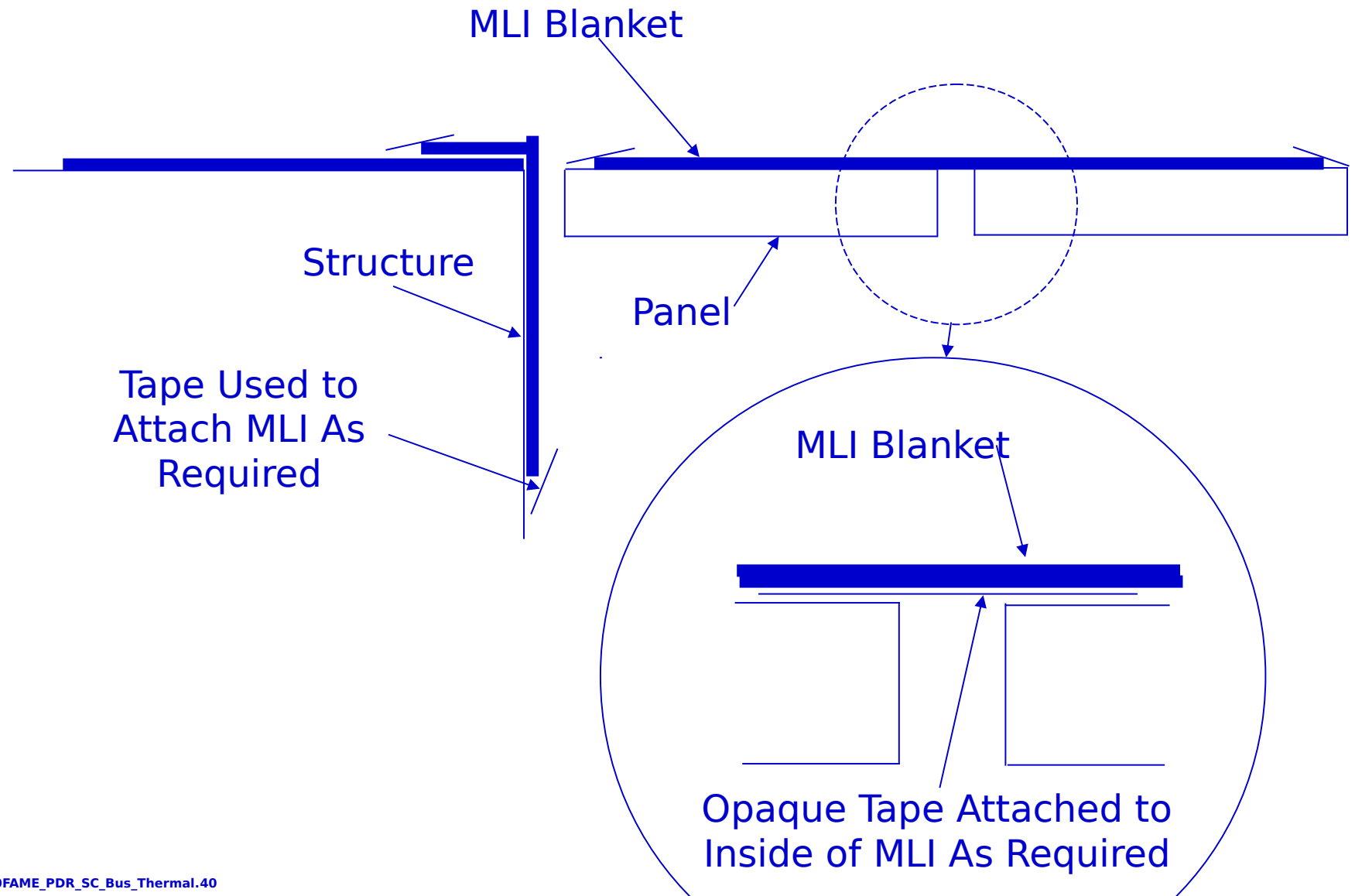
Separator Layer
- Loose Mesh

Inner Layer
- Supplied Perforated

Reflector Layer
- Supplied Perforated

Tape
- 100% Continuous Coverage of Blanket Edge
- Opaque Material – Aluminized/ Black Kapton

Stray Light Prevention (4 of 5)



Stray Light Prevention (5 of 5)

- **Conclusion**
  - **MLI Design Prevents/Eliminates Light Path to Instrument Through Gaps in Electronics Deck**
    - **All Blanket Edges Closed Out With Opaque Tape**
    - **Any Exposed Interior Layers Covered With Opaque Tape**
    - **All Installations/Requirements Verified by Inspection**
    - **Glint From Blankets/Structure at Edge of Sun Shield Needs Further Study**

Optical Properties

	BOL		EOL	
	a	e	a	e
• Kapton	.39	.73	.67	.73
• Silver Teflon	.07	.80	.27	.80
• Solar Cells	.88	.90	.90	.85
• Black Kapton	.92	.88	.92	.88

Test Descriptions

- **Thermal Design Verification Test (TDVT)**
  - **To Be Performed on Engineering Model**
  - **Simulated Electronics**
  - **Simulated Solar Flux Using Surface Heaters**
  - **Simulated Instrument**
- **Marmon Clamp Joint Conductance Test**
  - **Clementine Heritage Hardware to Be Used**
  - **Various Clamping Pressures to Be Tested**

Component Failure Modes

- **Thermostats**
  - **Typically Fail Open – 2 Switches Per Circuit Wired in Parallel**
  - **All Circuits Provided With Commandable Relay**
- **Heaters**
  - **Multiple Elements Wired in Parallel**
- **Thermistors**
  - **Sufficient Numbers in Key Locations**

Component Failure Modes

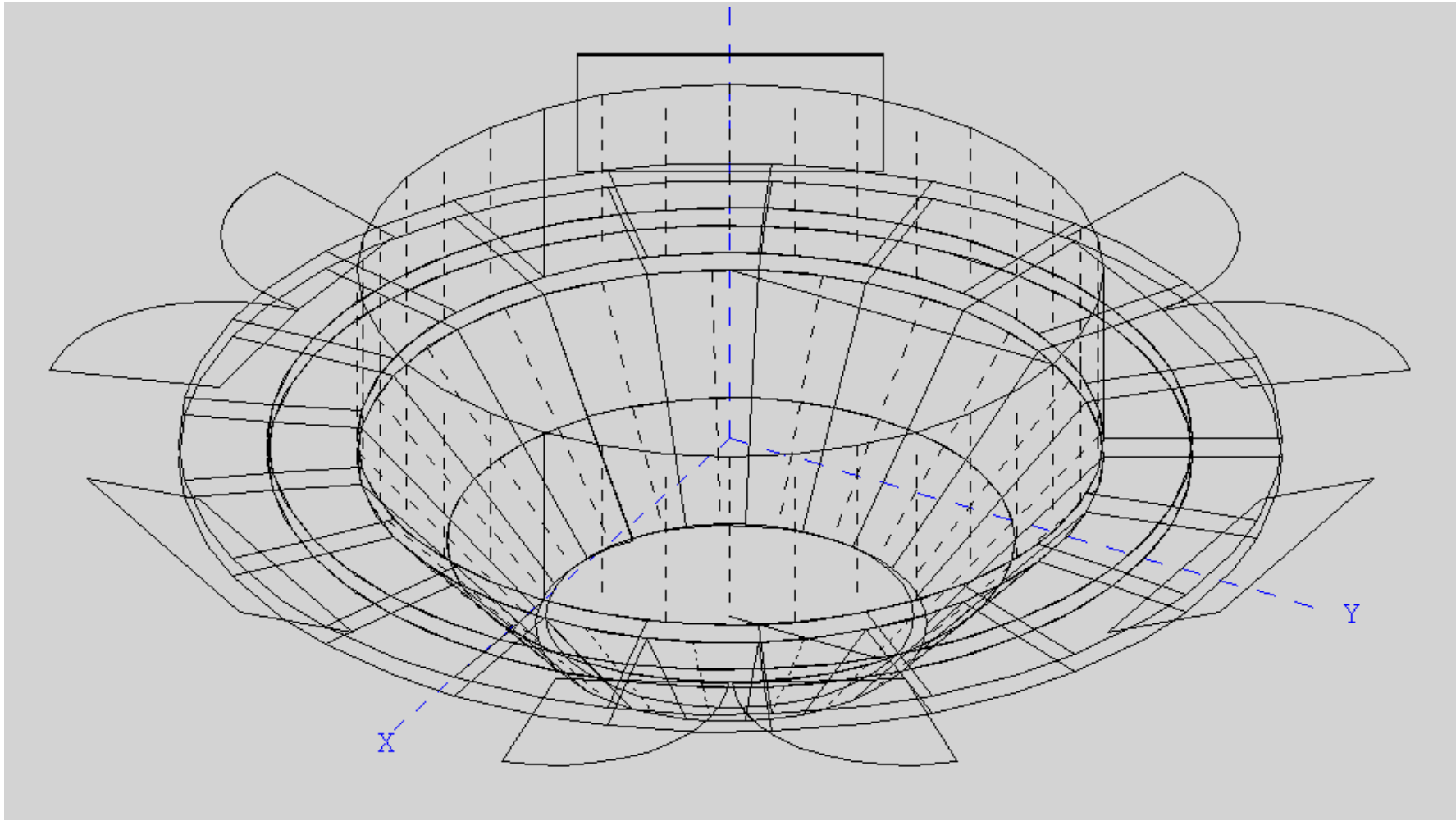
- **Optical Surfaces**
  - **Contamination From Various Sources**
  - **Identified/prevented by the Following:**
    - **Plume Analysis**
    - **Venting Analysis**
    - **Material Selection**
      - **Instrument Also Requires These Efforts**

Analysis

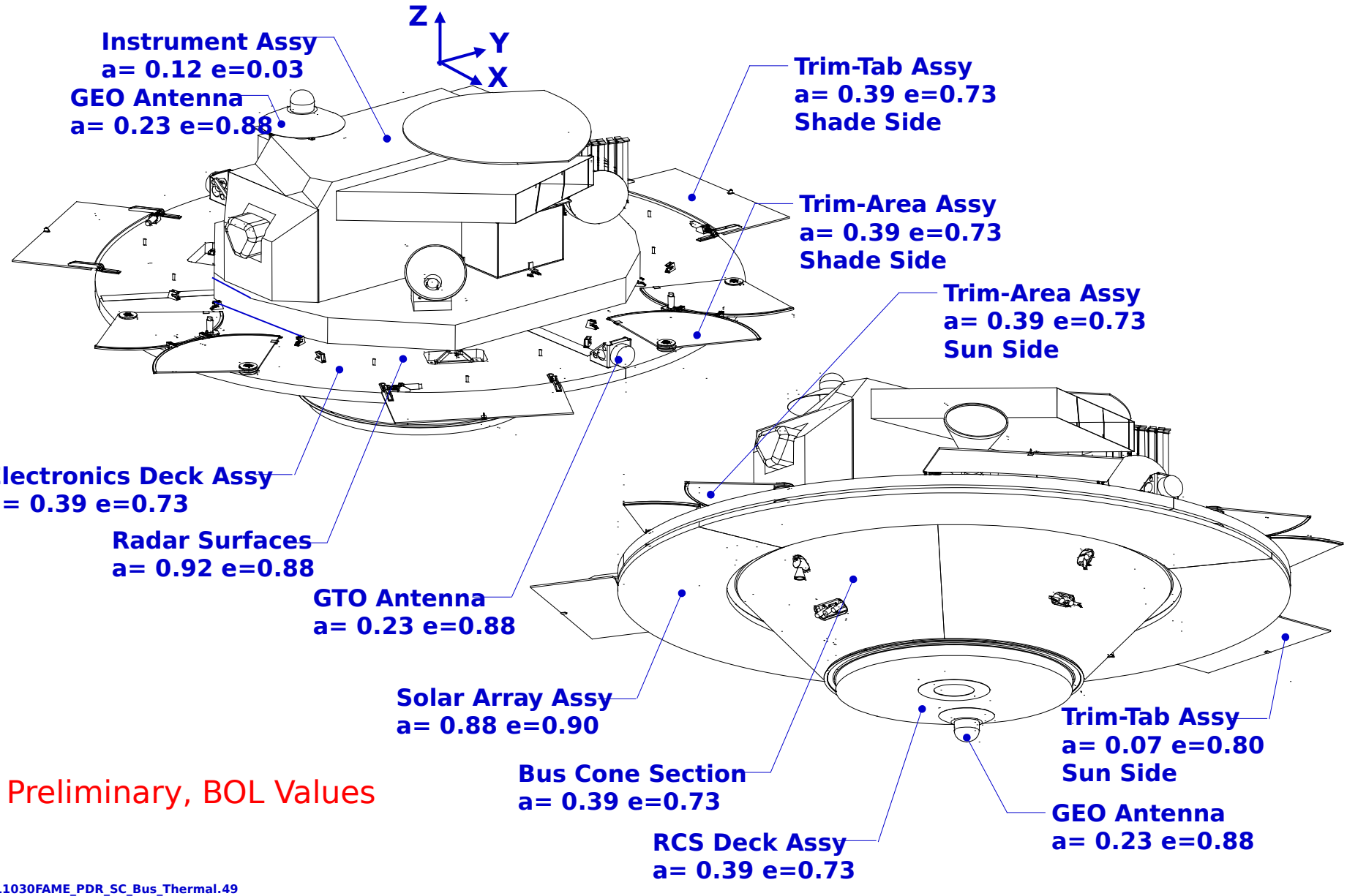
Analysis

- **Passive Design**
- **Thermal Model**
  - **TRASYS/SINDA85 Analysis Codes**
- **Analysis Cases**
  - **Launch**
  - **Acquisition**
  - **AKM Burn/Jettison**
  - **Drift to Mission Node**
  - **Mission Life/Eclipse**
  - **Disposal**

TRASYS Model

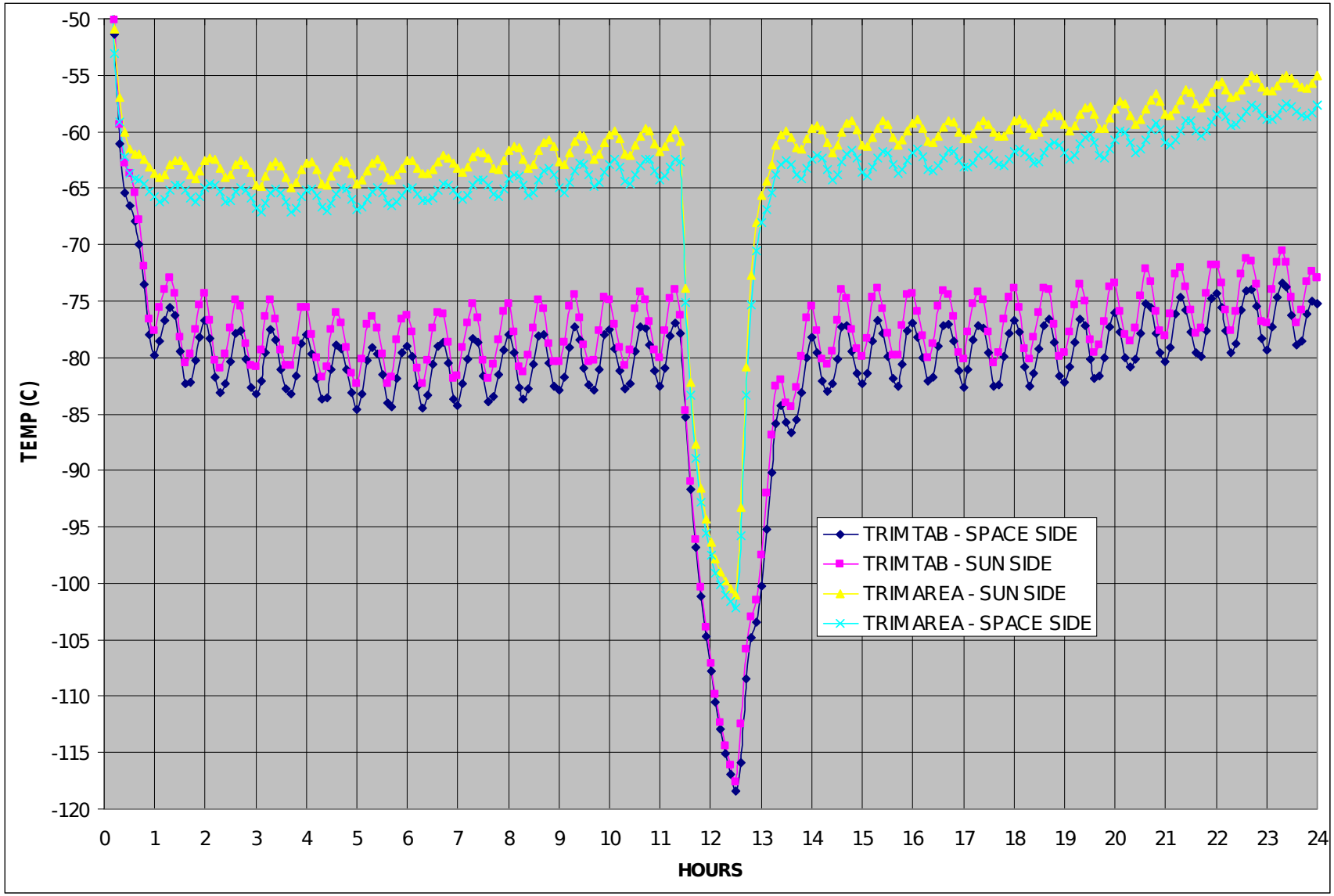


Optical Properties



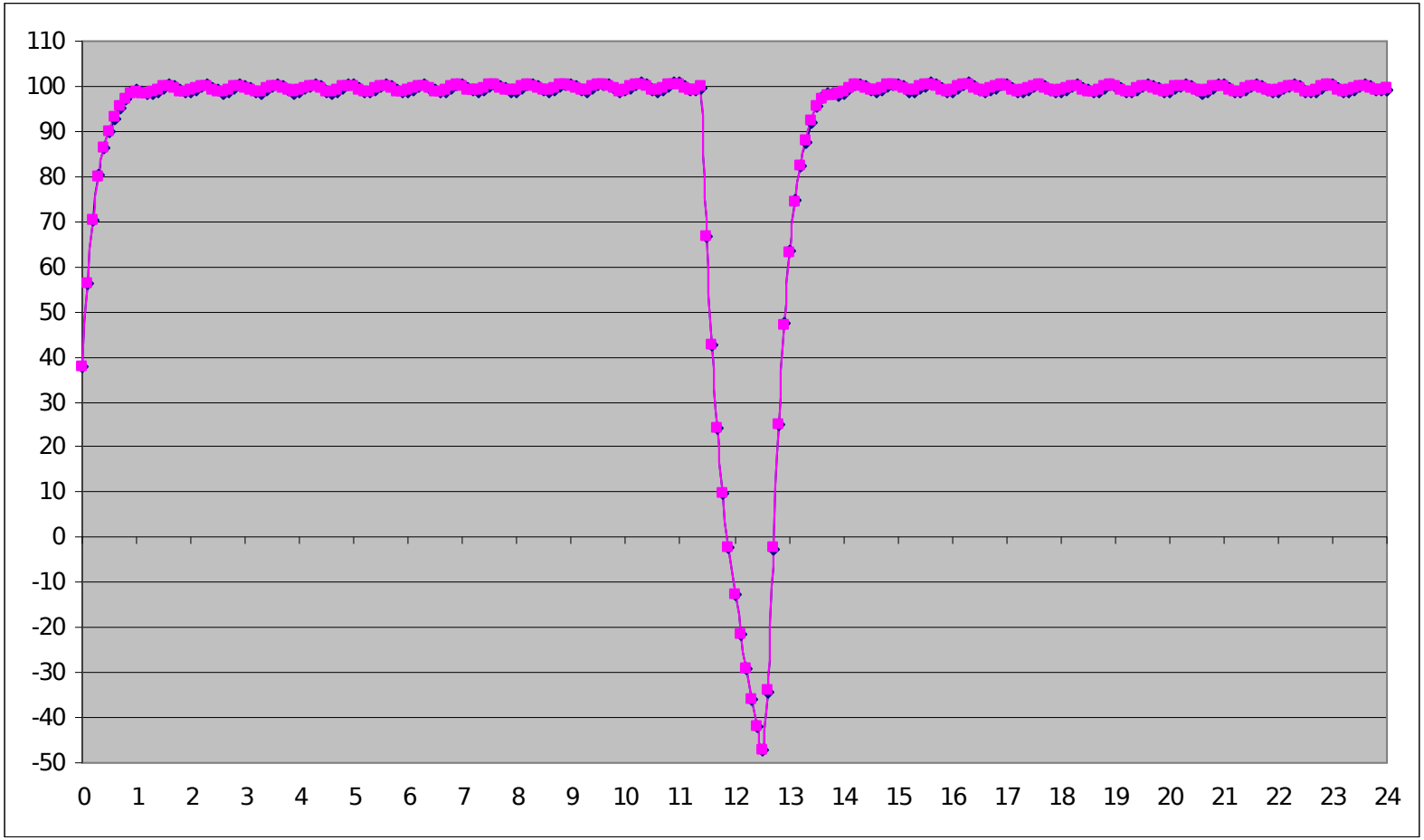
Preliminary, BOL Values

Trim Tab/Area Temps



Solar cells

- **Temperature Based on 90% (TBR) Packing Factor and Beginning of Life Optical Properties**



Forward Work

- **Trade Studies**
- **Detail Thermal Model**
  - **Hot and Cold Cases for All Mission Phases**
  - **Interface Orbital Temperature Fluctuations**
  - **Component Temperature Predictions**
  - **Detail External Surface Temperatures**
  - **Thermal Time Constants**
- **Optimize Optical Properties – Materials**
  - **Radiators**
  - **AKM Thermal Blankets**
  - **Deposited Conductive Materials**

Top Level Schedule

Task Name	Duration	Start	Finish
PDR	2 days?	Tue 10/30/01	Wed 10/31/01
CDR	4 days	Mon 8/5/02	Thu 8/8/02
TRR	1 day?	Mon 11/3/03	Mon 11/3/03
SHIP	4 days	Mon 8/9/04	Thu 8/12/04
LAUNCH	1 day?	Mon 10/4/04	Mon 10/4/04
TCS DESIGN / ANALYSIS	261 days?	Fri 8/10/01	Fri 8/9/02
Hardware Procurement	368 days?	Tue 1/15/02	Thu 6/12/03
Blanket Fabrication	367 days?	Fri 2/1/02	Mon 6/30/03
Thermal Integration	88 days?	Wed 4/16/03	Fri 8/15/03
Thermal Design Verification Test	12 days?	Fri 8/15/03	Mon 9/1/03
Spacecraft Complete	1 day?	Mon 11/3/03	Mon 11/3/03
System Level Testing	176 days?	Mon 12/1/03	Mon 8/2/04